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The effects of different methods of new sward ɪtablishment and the effects of the herbicides paraquat and dalapon on the soil fauna

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With 12 Figures

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1. Introduction

Grassland improvement by the traditional method of cultivation and reseeding ıstically affects the soil as a habitat for soil animals. There is much evidence that tivation, particularly the ploughing up of pasture land, considerably reduces the ɔulation and diversity of the fauna as a whole (Buckle 1921; Hammer 1949; Sheals 56; Raw 1967 and others). The effects of cultivation appear to vary with the different mal groups: some groups appear to be favoured and may actually increase in numbers ɔwards 1929), but the majority appear to be adversely affected.

Surface seeding following chemical destruction of the sward and some surface cultiion involves less disturbance of the soil than does cultivation and reseeding. The ɜstions arise as to whether this method has correspondingly less drastic effects on the na and whether the chemicals used are themselves detrimental to soil animals. The ɛcts of some herbicides on the fauna have been investigated. Baudissin (1952) reported t the sodium salt of 2,4-D caused a slight increase in the population of soil Collembola l a smaller one in Acari and Nematoda. Van der Drift (1963) found that DNOC htly affected the surface-dwelling soil invertebrates, particularly the Collembola, terous and lepidopterous larvae, and earthworms. Rapoport and Cangioli (1963) nd that 2,4-D and MCPA do not affect the total density of soil microarthropods in ' appreciable manner. Fox (1964) found that atrazine caused a reduction in the numbers ɣireworms, earthworms and springtails in grassland soil and monuron caused a reduc- ı in the numbers of wireworms, millipedes, springtails and mites. Dalapon and TCA ·eased the numbers of millipedes, springtails and mites, but TCA decreased the number arthworms. Treatment with 2, 4-D did not affect the numbers of wireworms, springs or mites. He suggested that the herbicides exerted their effects indirectly by altering floristic composition of the sward. Karg (1964) found that DNOC caused a tempo- ' depression of Collembola and mites, followed by a rapid recovery and a population ease of up to 300%. He attributed this increase in population to an increase in food ɔly. Davis (1965) found no quantitative or qualitative differences between the fauna ılots of arable land that had received an annual application of MCPA herbicide for ɣears and similar untreated plots. Edwards (1965) reported that, of 4 herbicides ed (MCPA, tri-allate, simazine, and linuron) only simazine affected soil animals, ıcing populations to ⅓—½ of those in untreated soil. The predatory mites and iedaphic Collembola, particularly the Isotomidae, were most adversely affected by ɪzine, but the earthworms, enchytraeid worms, dipterous and coleopterous larvae,

and populations of other mites and springtails were all decreased and significant differences between the numbers of these in treated and untreated soil were still obvious 3—4 months after the chemical had been applied.

The effects of cultivation and reseeding, surface seeding after destruction of the sward with paraquat and surface seeding after destruction of the sward with dalapon on soil arthropod populations were studied in a field experiment on an old grassland site at Lyons hill, Celbridge, Co. Kildare and, in a separate experiment on the same site, the effects on the fauna of the herbicides paraquat and dalapon without surface cultivation or reseeding were studied.

2. Methods

The soil was a silty clay loam derived from the underlying Silurian country rock, of low to medium base status, of good crumb structure and free-draining. The main constituents of the vegetation were *Agrostis tenuis* and *Festuca rubra*, which between them accounted for about 75% of the total oven-dry weight of the herbage. The arthropod fauna of the site has been described in an earlier paper (CURRY 1969).

A randomised block experiment (Experiment I) consisting of 3 blocks of 4 plots each was laid out on this site in February 1965. Plots were 4.6 m by 4.6 m in size and a space of 1 m was left between adjacent plots, the area between plots being left uncultivated. Each plot received one of the following 4 treatments at random: (1) Uncultivated control, (2) Cultivation and reseeding, (3) Surface seeding after destruction of the sward with paraquat, (4) Surface seeding after destruction of the sward with dalapon.

Each treatment was represented once in each block, giving in all three replications of each treatment. The cultivated plots were dug over roughly to simulate ploughing in early February, were left to weather until early April, and cultivation was then continued until a fine tilth was obtained. The dalapon treatment was applied at the rate of 17 kg/ha. 'Dowpon' and the paraquat treatment at the rate of 11 l/ha. 'Gramoxon W', the chemicals being dissolved in water and applied with a hand sprayer. In early April the dalapon and paraquat-treated plots were surface cultivated by raking vigorously with a garden rake. Ground limestone at the rate of 7500 kg/ha and compound fertilizer (8% N, 6% P and 16% K) at the rate of 750 kg/ha were applied to all plots. Plots other than controls were then seeded with a grass-clover mixture at the rate of 22 kg/ha. S. 23 Perennial ryegrass and 4.5 kg/ha. New Zealand White clover. Grazing animals were excluded until June to facilitate sward establishment but were allowed in from then until late October and were excluded for the remainder of the period of study. The grass was mown in June 1966 and again in September of that year. On each of 5 dates, 4 core samples of surface area 25 cm^2 and 7.5 cm deep were taken per plot. The five sampling dates were 5th May, 7th July, 15th November 1965 and 7th March and 9th November 1966.

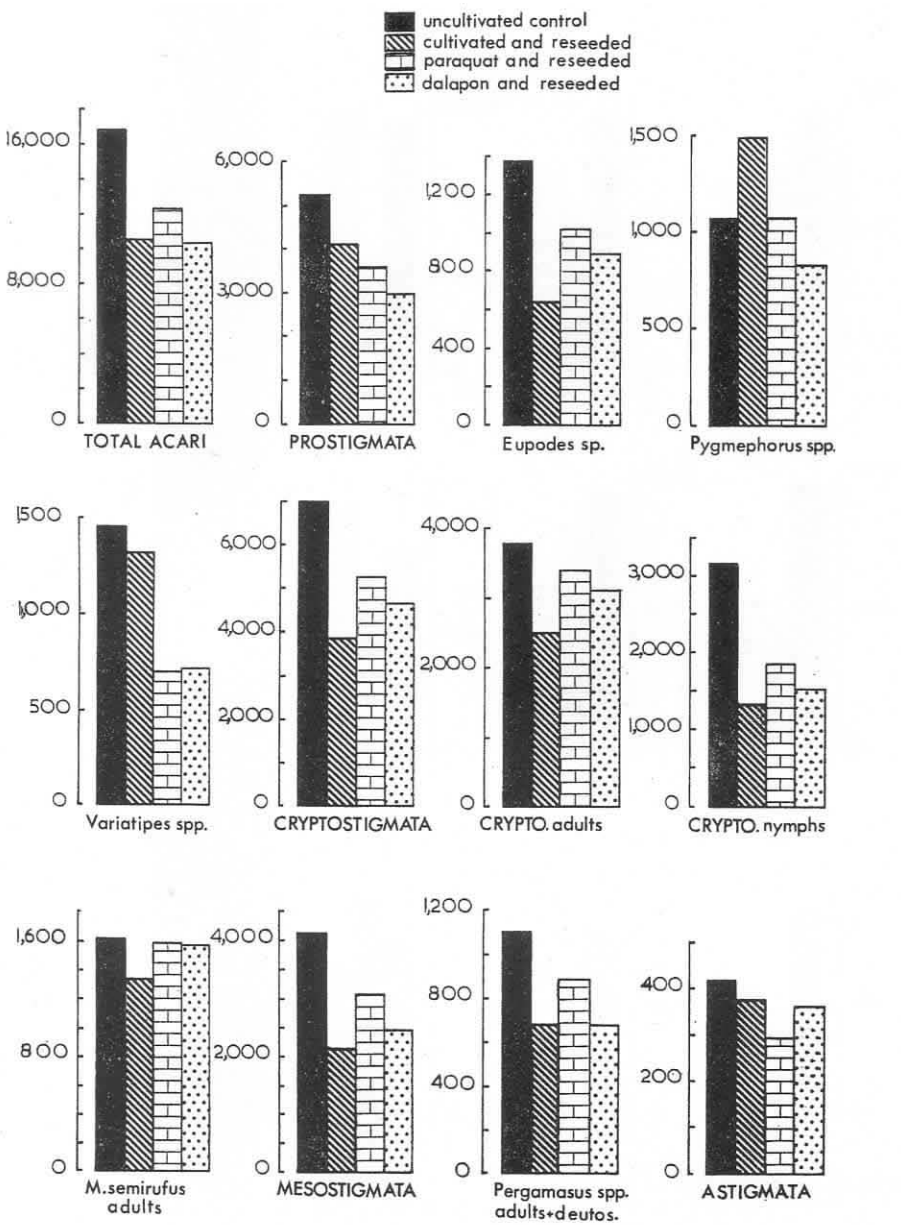
A second randomised block experiment (Experiment II) consisting of 2 blocks of 3 plots each adjacent to Experiment I was initiated in July 1965. The plots were 2.1 m by 2.1 m in size and a space of 1 m was left between adjacent plots, this space being left untreated. Each plot received one of the following 3 treatments at random: (1) Old grassland control, (2) Paraquat, (3) Dalapon.

Each treatment being represented once in each block. The herbicides were applied on the 16th of July 1965 by means of a hand sprayer at rates identical to those used in Experiment I. Four core soil samples per plot were taken to a depth of 3.8 cm on each of three sampling dates — 26th August 1965, 5th January and 12th May 1966. The fauna was extracted in a high gradient extractor as described elsewhere (CURRY 1969).

3. Results of experiment I

3.1. Quantitative effects of treatments

Overall effects of the treatments on populations of the main arthropod groups and species are shown in Figs. 1 and 2 and the effects of treatments with time are summarised in Figs. 3—6. Analysis of variance was carried out on the data, the data having been first fractional power transformed in order to stabilish the variance (see TAYLOR 1961). Treatment means were compared using Duncan's new multiple range test (DUNCAN 1955). The results of these analyses are presented in Tables 1—7.



1. Overall effects of treatments, May 1965—November 1966. Total numbers from 60 samples.

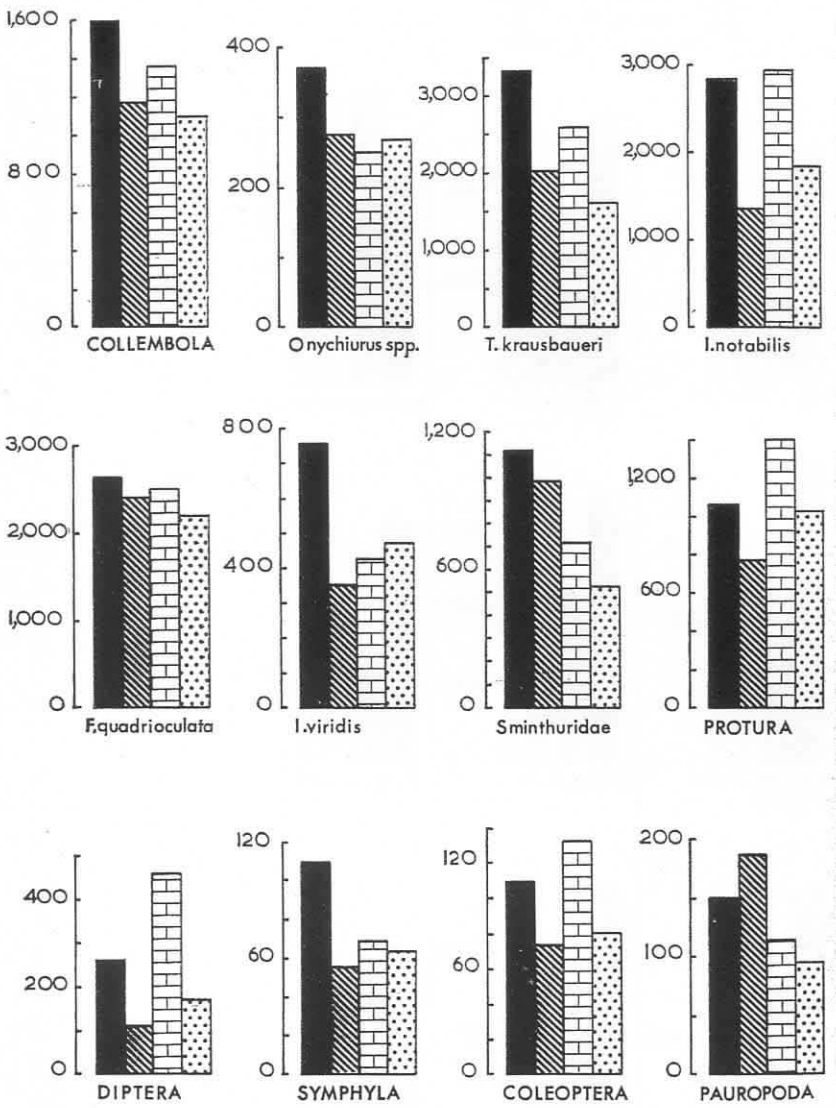


Fig. 2. Overal effects of treatments (continued).

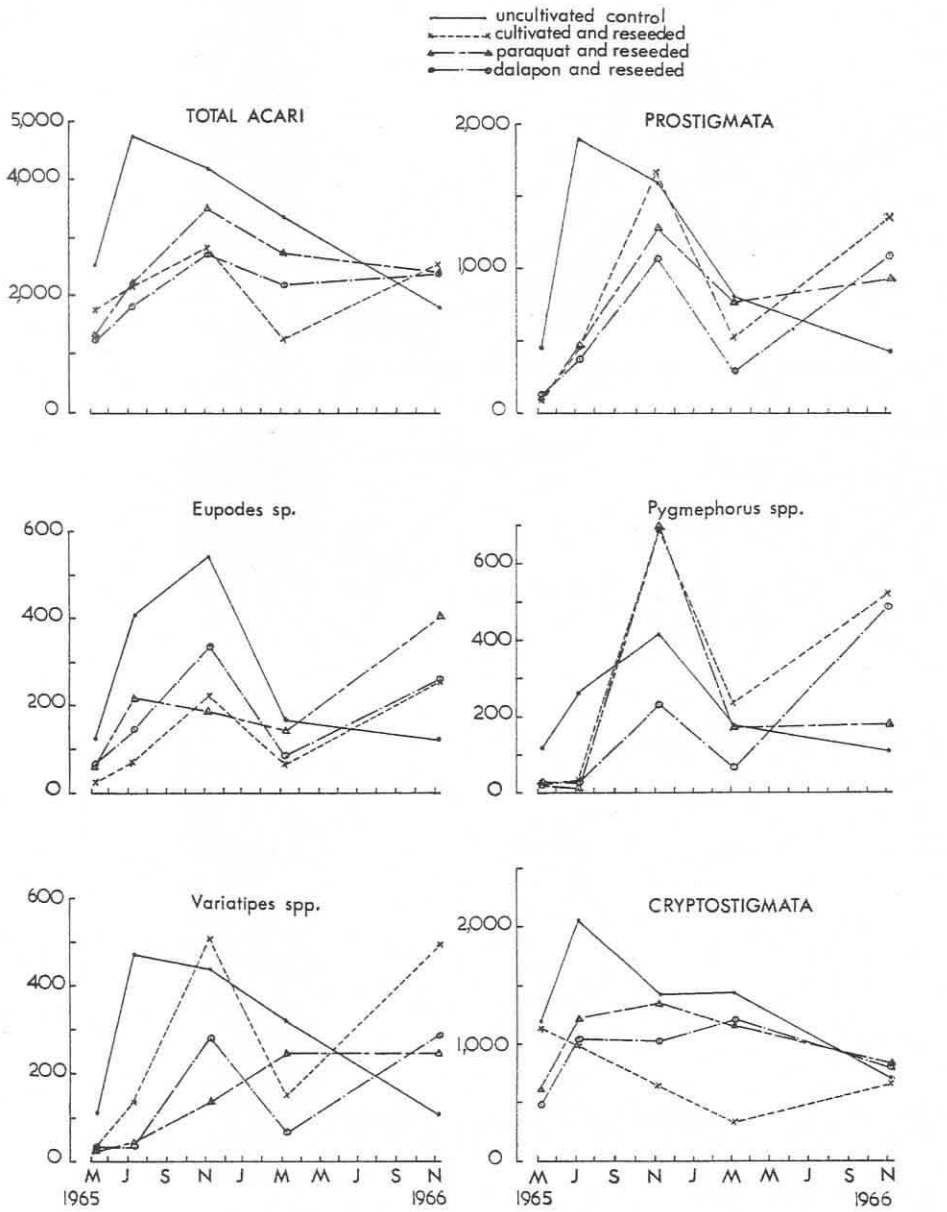


Fig. 3. Interaction of treatments with time, May 1965—November 1966. Total numbers from 12 samples.

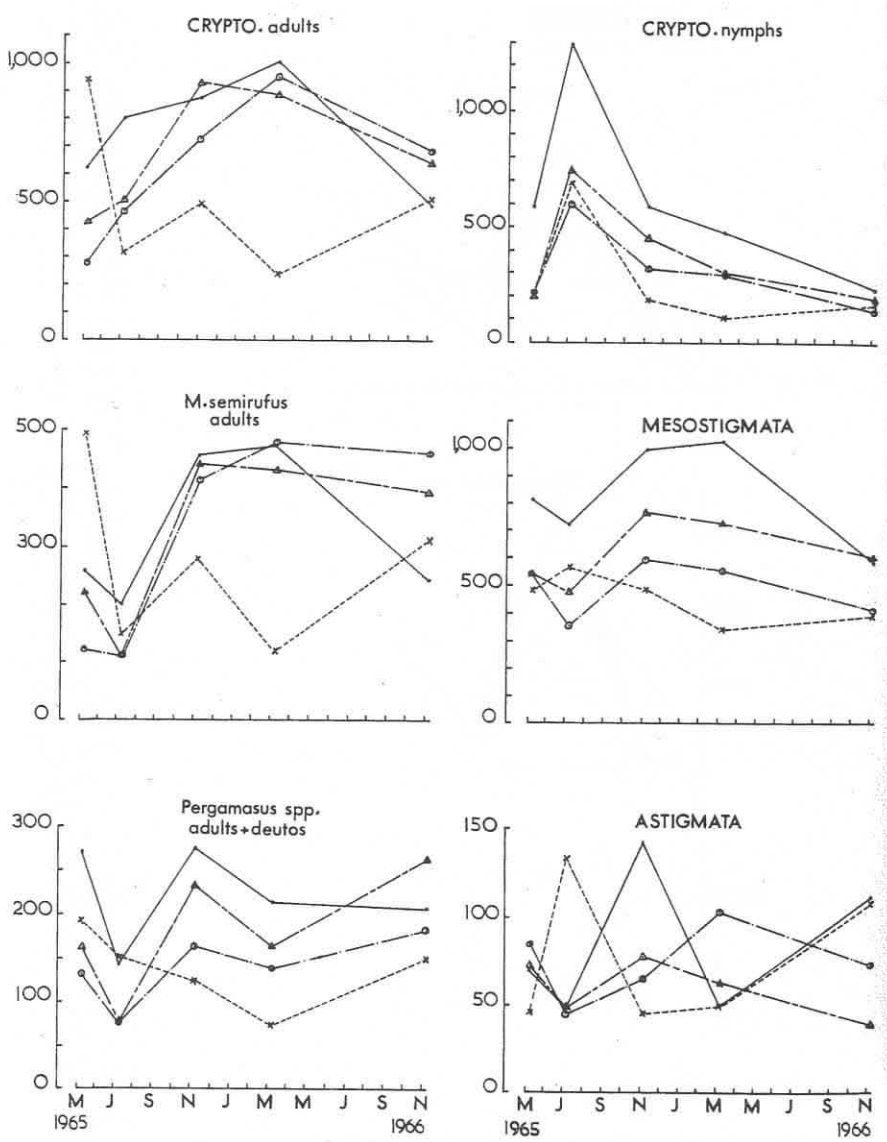


Fig. 4. Interaction of treatments with time (continued).

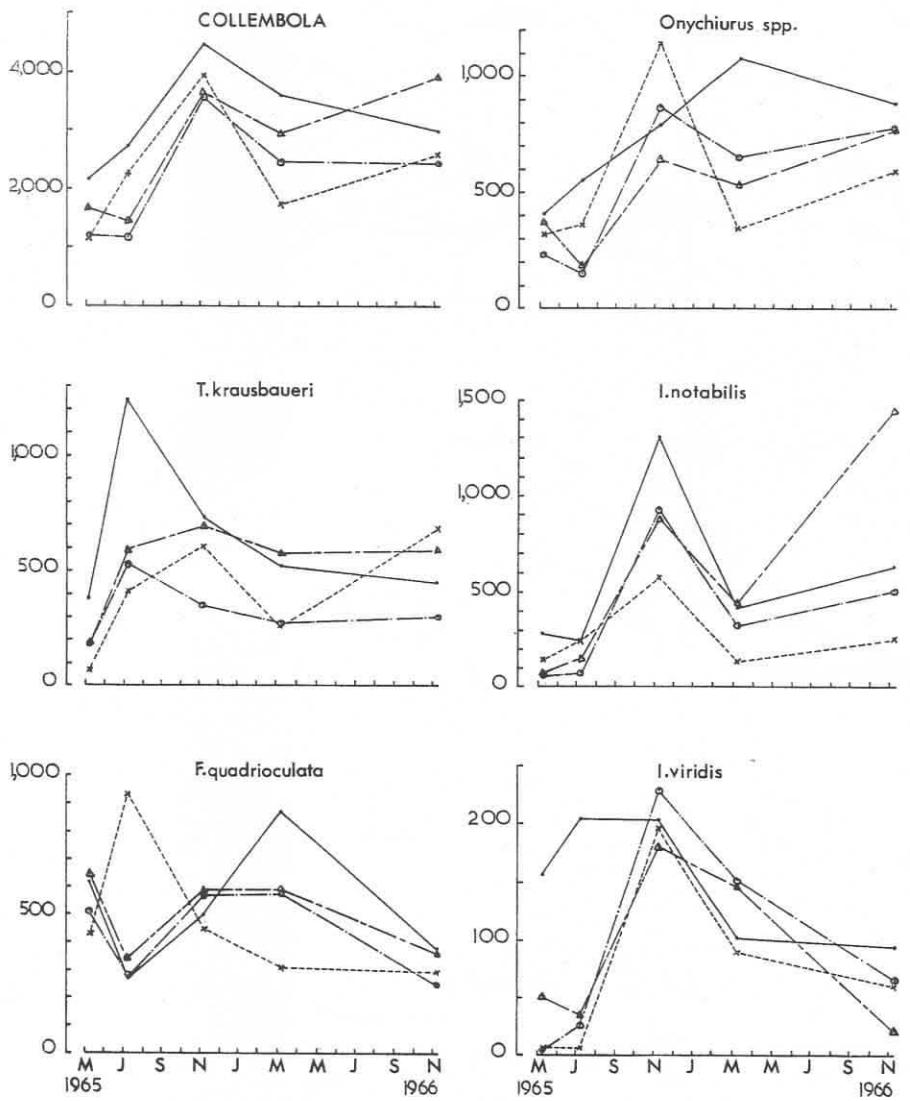


Fig. 5. Interaction of treatments with time (continued).

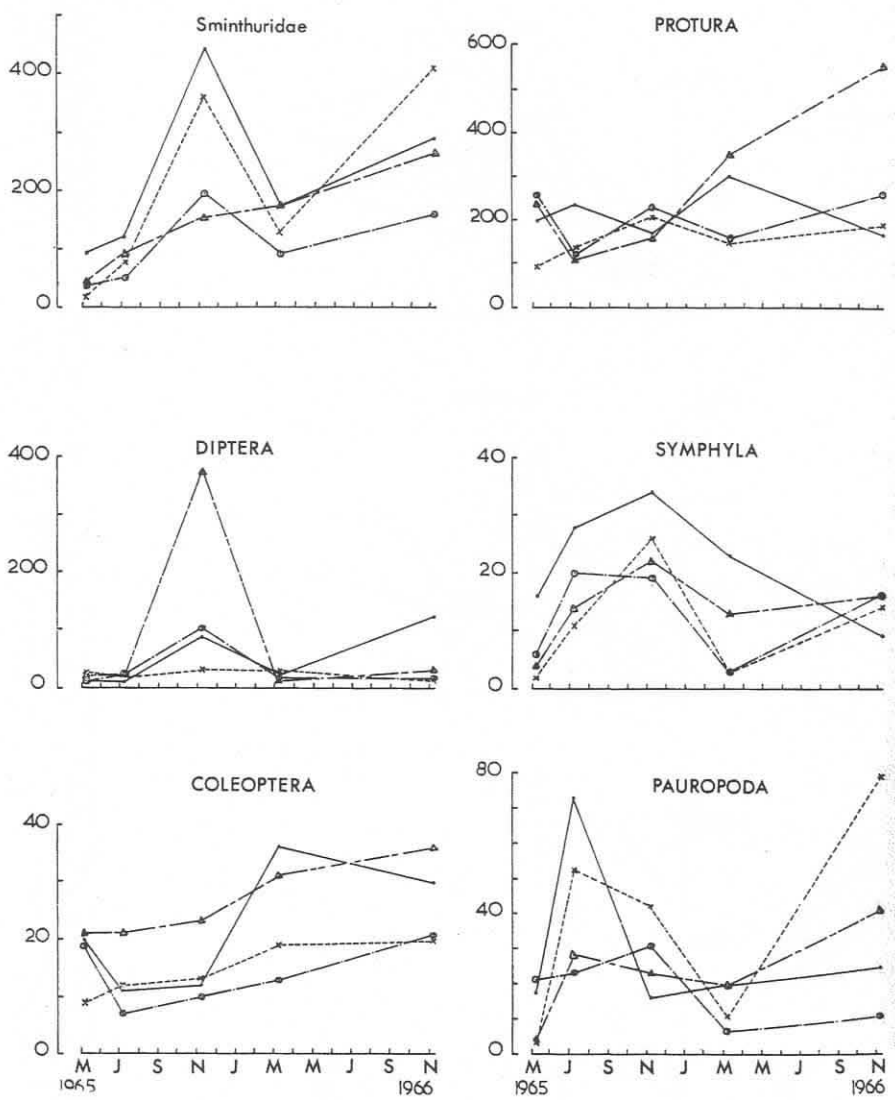


Fig. 6. Interaction of treatments with time (continued).

Table 1 Results of analysis of data of Experiment I. Variance ratios

Group or species	May '65—Nov. '65 overall		5/5/'65 1st sampling	7/7/'65 2nd sampling	15/11/'65 3rd sampling	7/3/'66 4th sampling	9/11/'66 5th sampling
	F (treatments)	F (t×s)	F (treatments)	F (treatments)	F (treatments)	F (treatments)	F (treatments)
Total Acari	8.39*	2.77*	14.1**	9.29*	5.6*	5.52*	0.3
Prostigmata	2.0	6.8**	3.27	7.91*	2.88	3.95	3.44
Eupodes sp.	4.00	4.01**	3.63	5.71*	12.80**	0.64	12.06**
Pygmephorus spp.	1.85	5.69**	4.96*	8.18*	2.75	1.59	3.52
Variatipes spp.	2.45	4.08**	2.06	33.43**	7.66*	1.99	0.49
Cryptostigmata (total)	11.72**	2.63*	8.76*	7.86*	9.58*	5.32*	0.45
Cryptostigmata (adults)	10.94**	3.24**	10.18**	9.18*	4.80*	6.91*	1.07
Cryptostigmata (nymphs)	17.14**	1.34	1.64	5.84*	27.29**	8.30*	1.22
Minunthozetes semirufus (C. L. K.)	1.33	2.9**	10.75**	0.49	1.76	2.92	1.67
Mesostigmata	52.28**	1.03	4.88*	2.13	25.43**	13.83**	1.27
Pergamasus spp.	6.44*	1.57	2.25	2.38	4.5	3.45	0.84
Astigmata	0.11	1.5	0.105	0.85	2.2	0.47	2.35
Total Collembola	4.19	1.5	4.56	4.63	1.34	2.12	7.5*
Onychiurus spp.	1.70	0.93	0.67	10.4**	0.38	1.15	0.3
Tullbergia krausbaueri (Börn.)	1.90	2.55*	3.38	2.55	1.8	1.54	2.83
Isotoma notabilis Schäff.	2.59	2.72*	2.43	4.39	4.59	1.83	12.54**
Folsomia quadrioculata (Tullb.)	0.76	1.33	0.93	1.90	1.69	2.84	0.4
Isotoma viridis Bourl.	7.68*	5.71**	15.94**	23.69**	1.01	1.97	1.03
Sminthuridae	2.02	2.66*	1.99	1.00	11.4**	1.0	4.80*
Protura	1.27	1.62	4.40	2.00	1.14	13.7**	1.30
Diptera	0.35	1.51	0.93	0.25	2.06	0.68	2.69
Symphyla	6.12*	1.51	1.56	1.19	3.52	3.57	1.93
Coleoptera	3.24	0.57	2.02	1.24	1.74	1.22	1.15
Pauropoda	3.20	1.95	1.9	1.78	4.98*	11.17**	2.38

F (treatments) with degrees of freedom $f_1 = 3$, $f_2 = 6$, *P 0.05 = 4.76, **P 0.01 = 9.78.

F (t × s = treatments × sampling dates) with degrees of freedom $f_1 = 12$, $f_2 = 32$, *P 0.05 = 2.07, **P 0.01 = 2.80.

Table 2 Results of comparisons of overall treatment means (May '65 — Nov. '66) by means of Duncan's New Multiple Range Test. Analysis of fractional power transformed data

Group or species	Treatment means*)			
Total Acari	T_2 1.9110	T_4 1.9146	T_3 1.9567	T_1 2.0413
Prostigmata	T_4 1.4744	T_2 1.5470	T_3 1.5533	T_1 1.7339
Eupodes sp.	T_2 0.2898	T_4 0.3629	T_3 0.3696	T_1 0.4184
Pygmephorus spp.	T_4 2.0276	T_3 2.1957	T_2 2.6867	T_1 2.9370
Variatipes spp.	T_4 1.5819	T_3 1.6748	T_2 2.1206	T_1 2.5789
Cryptostigmata (total)	T_2 2.4826	T_4 2.6417	T_3 2.7611	T_1 2.9586
Cryptostigmata (adults)	T_2 .5909	T_4 .6587	T_3 .7039	T_1 .7325
Cryptostigmata (nymphs)	T_2 1.9200	T_4 2.0519	T_3 2.1572	T_1 2.4335
Minunthozetes semirufus (C. L. K.)	T_2 1.4077	T_4 1.4549	T_3 1.4815	T_1 1.4981
Mesostigmata	T_2 .7914	T_4 .8251	T_3 .8788	T_1 .9529
Pergamasus spp.	T_4 1.2733	T_2 1.2817	T_3 1.3164	T_1 1.3613
Astigmata	T_4 1.3315	T_3 1.3782	T_2 1.4376	T_1 1.5320
Total Collembola	T_4 2.8136	T_2 2.8545	T_3 2.9657	T_1 3.0922
Onychiurus spp.	T_4 1.0711	T_3 1.0732	T_2 1.0751	T_1 1.0854
Tullbergia krausbaueri (Börn.)	T_4 1.2154	T_2 1.2321	T_3 1.2654	T_1 1.2797
Isotoma notabilis Schäff.	T_2 1.2559	T_4 1.2711	T_3 1.3166	T_1 1.3590
Folsomia quadrioculata (Tullb.)	T_2 1.4705	T_4 1.4789	T_1 1.5197	T_3 1.5275
Isotoma viridis Bourl.	T_2 1.7637	T_3 2.3704	T_4 2.4594	T_1 3.3544
Sminthuridae	T_4 1.00728	T_3 1.00848	T_2 1.00893	T_1 1.01011
Protura	T_2 1.2236	T_4 1.2301	T_1 1.2682	T_3 1.2706
Diptera	T_2 1.6871	T_1 1.6905	T_3 2.0755	T_4 2.0774

Table 2 (Cont.)

Group or species	Treatments means*)			
Symphyla	T_2 0.7762	T_4 0.9888	T_3 1.1327	T_1 1.7774
Coleoptera	T_2 0.9934	T_4 1.0999	T_1 1.6515	T_3 2.0054
Pauropoda	T_4 1.2217	T_3 1.7203	T_1 2.2935	T_2 2.2980

*) T_1 = Old grassland (control), T_2 = cultivated and reseeded, T_3 = paraquat and reseeded, T_4 = dalapon and reseeded. Means underscored by the same line do not differ significantly. Continuous lines indicate 95 % level and broken lines indicate 99 % level of significance.

Table 3 Results of comparisons of treatment means on the first sampling date (5/5/'65) by means of Duncan's New Multiple Range Tests. Analysis of fractional power transformed data

Group or species	Treatment means*)			
Total acari	T_4 1.8106	T_3 1.8309	T_2 1.8745	T_1 1.9824
Prostigmata	T_2 0.7989	T_3 0.9334	T_4 0.9798	T_1 1.3935
Eupodes sp.	T_2 0.0723	T_4 0.2063	T_3 0.2191	T_1 0.2697
Pygmephorus spp.	T_3 0.7741	T_4 0.7969	T_2 0.87625	T_1 2.3817
Variatipes spp.	T_3 0.6770	T_2 0.7977	T_4 0.9110	T_1 1.8386
Cryptostigmata (total)	T_4 2.2997	T_3 2.4834	T_2 2.8307	T_1 2.8761
Cryptostigmata (adults)	T_4 .5352	T_3 .6447	T_1 .7127	T_2 .7650
Cryptostigmata (nymphs)	T_3 1.8179	T_2 1.8608	T_4 1.8962	T_1 2.3389
Minunthozetes semirufus (C. L. K.)	T_4 1.2952	T_3 1.4645	T_1 1.4836	T_2 1.6126
Mesostigmata	T_2 0.7755	T_3 0.8621	T_4 0.8709	T_1 0.9508
Pergamasus spp.	T_4 1.2726	T_3 1.3159	T_2 1.3368	T_1 1.3984
Astigmata	T_2 1.0844	T_4 1.2627	T_3 1.3597	T_1 1.4753
Total Collembola	T_4 2.4949	T_2 2.5092	T_3 2.6975	T_1 2.8235
Onychiurus spp.	T_4 1.0608	T_3 1.0682	T_2 1.0685	T_1 1.0702

Table 3 (Cont.)

Group or species	Treatment means*)			
Tullbergia krausbaueri (Börn.)	T_2 1.0983	T_4 1.1676	T_3 1.1822	T_1 1.2196
Isotoma notabilis Schäff.	T_4 1.1023	T_3 1.1279	T_2 1.1908	T_1 1.2884
Folsomia quadriculata (Tullb.)	T_2 1.4624	T_4 1.5031	T_1 1.5208	T_3 1.5887
Isotoma viridis Bourl.	T_4 0.1399	T_2 0.2562	T_3 0.90295	T_1 3.0126
Sminthuridae	T_2 1.00125	T_3 1.00303	T_4 1.00372	T_1 1.00498
Protura	T_2 1.1660	T_1 1.2610	T_3 1.2907	T_4 1.2970
Diptera	T_1 .6937	T_4 .7269	T_3 1.6231	T_2 1.9645
Symphyla	T_2 0.0000	T_3 0.2188	T_4 0.3191	T_1 1.0608
Coleoptera	T_2 0.5663	T_1 1.4822	T_4 1.5831	T_3 1.6230
Pauropoda	T_2 0.0000	T_3 0.0000	T_4 1.2522	T_1 1.2681

*) T_1 = old grassland (control), T_2 = cultivated and reseeded, T_3 = paraquat and reseeded, T_4 = dalapon and reseeded. Means underscored by the same line do not differ significantly. Continuous lines indicate 95 % level and broken lines indicate 99 % level of significance.

Table 4 Results of comparisons of treatments means on the second sampling date (7/7/'65) by means of Duncan's New Multiple Range Test. Analysis of fractional power transformed data

Group or species	Treatment means*)			
Total Acari	T_4 1.8943	T_2 1.9370	T_3 1.9494	T_1 2.1609
Prostigmata	T_4 1.4293	T_2 1.4720	T_3 1.4776	T_1 2.0910
Eupodes sp.	T_2 0.2616	T_4 0.3445	T_3 0.4191	T_1 0.5413
Pygmephorus spp.	T_3 0.2803	T_4 1.0056	T_2 1.2237	T_1 3.2002
Variatipes spp.	T_3 0.9819	T_4 1.0714	T_2 1.7690	T_1 3.3844
Cryptostigmata (total)	T_2 2.7864	T_4 2.8129	T_3 2.9455	T_1 3.3517
Cryptostigmata (adults)	T_2 .5742	T_4 .6366	T_3 .6709	T_1 .7715
Cryptostigmata (nymphs)	T_4 2.5062	T_2 2.6028	T_3 2.6621	T_1 3.0442

Table 4 (Cont.)

Group or species	Treatment means*)			
Minunthozetes semirufus (C. L. K.)	T_2 1.32215	T_4 1.3235	T_3 1.3339	T_1 1.4159
Mesostigmata	T_4 .7159	T_3 .7949	T_2 .8375	T_1 .9330
Pergamasus spp.	T_4 1.1882	T_3 1.2039	T_2 1.2983	T_1 1.3015
Astigmata	T_4 1.0672	T_1 1.2025	T_3 1.2093	T_2 2.0025
Total Collembola	T_4 2.5167	T_3 2.6297	T_2 2.8529	T_1 3.0282
Onychiurus spp.	T_4 1.0521	T_3 1.0531	T_2 1.0658	T_1 1.0806
Tullbergia krausbaueri (Börn.)	T_2 1.2582	T_4 1.2741	T_3 1.2861	T_1 1.3630
Isotoma notabilis Schäff.	T_4 1.1417	T_3 1.1764	T_2 1.2417	T_1 1.2901
Folsomia quadrioculata Tullb.)	T_4 1.3951	T_1 1.4198	T_3 1.4586	T_2 1.5770
Isotoma viridis Bourl.	T_2 0.2105	T_4 1.26385	T_3 1.8812	T_1 4.4048
Sminthuridae	T_4 1.00401	T_2 1.00650	T_3 1.0075	T_1 1.008375
Protura	T_3 1.1216	T_4 1.1735	T_2 1.1884	T_1 1.2835
Diptera	T_1 0.7199	T_2 1.1193	T_3 1.3160	T_4 1.7936
Symphyla	T_2 0.7568	T_3 1.2373	T_4 1.8364	T_1 2.6542
Coleoptera	T_4 0.4752	T_1 0.8592	T_2 0.9503	T_3 1.6699
Pauropoda	T_4 1.9623	T_3 2.4427	T_2 3.2139	T_1 4.7052

*) T_1 = old grassland (control), T_2 = cultivated and reseeded, T_3 = paraquat and reseeded, T_4 = dalapon and reseeded. Means underscored by the same line do not differ significantly. Continuous lines indicate 95 % level and broken lines indicate 99 % level of significance.

Table 5 Results of comparisons of treatment means on the third sampling date (15/11/'65) by means of Duncan's New Multiple Range test. Analysis of fractional power transformed data

Group or species	Treatment means*)			
Total Acari	T_2 1.9855	T_4 2.0051	T_3 2.0465	T_1 2.1223
Prostigmata	T_4 1.8299	T_3 1.8464	T_2 1.9932	T_1 2.0205
Eupodes sp.	T_3 0.3891	T_2 0.4181	T_4 0.5050	T_1 0.5751
Pygmephorus spp.	T_4 2.7418	T_3 3.5962	T_1 3.8067	T_2 4.2927
Variatipes spp.	T_3 1.9426	T_4 2.3103	T_2 3.2014	T_1 3.2197
Cryptostigmata (total)	T_2 2.4033	T_4 2.7816	T_3 2.9499	T_1 3.0659
Cryptostigmata (adults)	T_2 .5696	T_4 .7196	T_3 .7422	T_1 .7771
Cryptostigmata (nymphs)	T_2 1.8209	T_4 2.1483	T_3 2.3498	T_1 2.5104
Minunthozetes semirufus (C. L. K.)	T_2 1.4293	T_3 1.5426	T_4 1.5535	T_1 1.5909
Mesostigmata	T_2 .8106	T_4 .8805	T_3 .9297	T_1 .9996
Pergamasus spp.	T_2 1.2714	T_4 1.3157	T_3 1.3676	T_1 1.4088
Astigmata	T_2 1.2574	T_4 1.4530	T_3 1.9151	T_1 2.1456
Total Collembola	T_4 3.1851	T_3 3.1941	T_2 3.1992	T_1 3.3615
Onychiurus spp.	T_3 1.0807	T_4 1.0859	T_1 1.0905	T_2 1.0926
Tullbergia krausbaueri (Börn.)	T_4 1.2166	T_2 1.2823	T_3 1.2928	T_1 1.3091
Isotoma notabilis Schäff.	T_2 1.3836	T_3 1.4336	T_4 1.4538	T_1 1.5002
Folsomia quadrioculata (Tullb.)	T_2 1.4953	T_1 1.5514	T_4 1.5663	T_3 1.5719
Isotoma viridis Bourl.	T_2 2.9145	T_1 3.7615	T_4 3.8941	T_4 4.1528
Sminthuridae	T_3 1.0096	T_4 1.0107	T_2 1.0133	T_1 1.0137
Protura	T_4 1.2237	T_3 1.2350	T_1 1.2456	T_2 1.2785
Diptera	T_2 2.3480	T_1 2.5907	T_3 3.4927	T_4 4.4946

Table 5 (Cont.)

Group or species	Treatment means*)			
Symphyla	T_4 1.2139	T_3 1.7769	T_2 2.2326	T_1 3.0193
Coleoptera	T_4 0.4752	T_2 0.6259	T_1 0.6672	T_3 1.6014
Pauropoda	T_1 1.3596	T_4 1.7622	T_3 1.8447	T_2 3.4270

*) T_1 = old grassland (control), T_2 = cultivated and reseeded, T_3 = paraquat and reseeded, T_4 = dalapon and reseeded. Means underscored by the same line do not differ significantly. Continuous lines indicate 95 % level and broken lines indicate 99 % level of significance.

Table 6 Results of comparisons of treatment means on the fourth sampling date (7/3/'66) by means of Duncan's New Multiple Range Test. Analysis of fractional power transformed data

Group or species	Treatment means*)			
Total Acari	T_2 1.7865	T_4 1.9107	T_3 1.9867	T_1 2.0468
Prostigmata	T_4 1.3474	T_2 1.5077	T_1 1.7123	T_3 1.7180
Eupodes sp.	T_2 0.2297	T_4 0.2926	T_3 0.3080	T_1 0.3627
Pygmephorus spp.	T_4 2.0101	T_2 2.5322	T_1 2.9487	T_3 3.1322
Variatipes spp.	T_4 1.2499	T_2 2.0591	T_3 2.3391	T_1 2.7377
Cryptostigmata (total)	T_2 1.9969	T_4 2.7358	T_3 2.7737	T_1 3.0075
Cryptostigmata (adults)	T_2 .4431	T_4 .7028	T_3 .7203	T_1 .7856
Cryptostigmata (nymphs)	T_2 1.5469	T_4 2.0321	T_3 2.0547	T_1 2.3207
Minunthozetes semirufus (C. L. K.)	T_2 1.2254	T_3 1.4977	T_4 1.5211	T_1 1.5847
Mesostigmata	T_2 0.7489	T_4 0.8536	T_3 0.9241	T_1 1.0030
Perqamasus spp.	T_2 1.1992	T_4 1.2734	T_3 1.3170	T_1 1.3585
Astigmata	T_2 0.8962	T_1 1.1531	T_3 1.3089	T_4 1.6377
Total Collembola	T_2 2.7278	T_4 2.9074	T_3 3.0547	T_1 3.1873
Onychiurus spp.	T_2 1.0652	T_4 1.0691	T_3 1.0776	T_1 1.0963

Table 6 (Cont.)

Group or species	Treatment means*)			
Tullbergia krausbaueri (BÖRN.)	T_4 1.1922	T_2 1.2063	T_1 1.2594	T_3 1.2732
Isotoma notabilis SCHÄFF.	T_2 1.1778	T_4 1.2774	T_1 1.3193	T_3 1.3382
Folsomia quadrioculata (TULLB.)	T_2 1.4223	T_4 1.5122	T_3 1.5702	T_1 1.6469
Isotoma viridis BOURL.	T_2 3.6063	T_3 4.1370	T_1 4.1719	T_4 4.7154
Sminthuridae	T_4 1.0081	T_2 1.0093	T_3 1.0103	T_1 1.0107
Protura	T_4 1.1964	T_2 1.2075	T_1 1.3145	T_3 1.3284
Diptera	T_3 0.9345	T_1 1.6173	T_4 1.7866	T_2 2.0698
Symphyla	T_2 0.0000	T_4 0.0000	T_3 1.1945	T_1 1.7148
Coleoptera	T_2 1.4778	T_4 1.5817	T_3 2.5248	T_1 2.6952
Pauropoda	T_4 0.2305	T_2 0.7318	T_1 1.7282	T_3 1.7694

*) T_1 = old grassland (control), T_2 = cultivated and reseeded, T_3 = paraquat and reseeded, T_4 = dalapon and reseeded. Means underscored by the same line do not differ significantly. Continuous lines indicate 95 % level and broken lines indicate 99 % level of significance.

Table 7 Results of comparisons of treatment means on the fifth sampling date (9/11/'66) by means of Duncan's New Multiple Range Test. Analysis of fractional power transformed data

Group or species	Treatment means*)			
Total Acari	T_1 1.8941	T_4 1.9522	T_3 1.9698	T_2 1.9716
Prostigmata	T_1 1.4521	T_4 1.7855	T_3 1.7910	T_2 1.9633
Eupodes sp.	T_1 0.3434	T_4 0.4660	T_2 0.4674	T_3 0.5128
Pygmephorus spp.	T_1 2.3477	T_4 3.1956	T_4 3.5837	T_2 4.5087
Variatipes spp.	T_1 1.7143	T_4 2.3671	T_3 2.4335	T_2 2.7758
Cryptostigmata (total)	T_2 2.3955	T_1 2.4918	T_4 2.5784	T_3 2.6528
Cryptostigmata (adults)	T_2 .6026	T_1 .6153	T_4 .6990	T_3 .7416
Cryptostigmata (nymphs)	T_4 1.6765	T_2 1.7686	T_3 1.9014	T_1 1.9535

Table 7 (Cont.)

Group or species	Treatment means*)			
Minunthozetes semirufus (C. L. K.)	T_1 1.4155	T_2 1.4489	T_3 1.5689	T_4 1.5811
Mesostigmata	T_2 0.7843	T_4 0.8046	T_1 0.8783	T_3 0.8834
Pergamasus spp.	T_2 1.3027	T_4 1.3170	T_1 1.3390	T_3 1.3775
Astigmata	T_3 1.1012	T_4 1.2370	T_1 1.6836	T_2 1.9478
Total Collembola	T_4 2.9666	T_2 2.9837	T_1 3.0603	T_3 3.2523
Onychiurus spp.	T_2 1.0831	T_3 1.0864	T_4 1.0876	T_1 1.0894
Tullbergia krausbaueri (Börn.)	T_4 1.2263	T_1 1.2475	T_3 1.2929	T_2 1.3158
Isotoma notabilis Schäff.	T_2 1.2854	T_4 1.3802	T_1 1.3968	T_3 1.5071
Folsomia quadrioculata (Tullb.)	T_2 1.3956	T_4 1.4178	T_3 1.4480	T_1 1.4598
Isotoma viridis Bourl.	T_3 1.0365	T_1 1.4210	T_2 1.8309	T_4 2.0251
Sminthuridae	T_4 1.0099	T_3 1.0120	T_1 1.0127	T_2 1.0143
Protura	T_1 1.2364	T_4 1.2600	T_2 1.2777	T_3 1.3774
Diptera	T_2 0.9337	T_4 1.5853	T_1 2.8308	T_3 3.0113
Symphyla	T_1 0.4377	T_2 0.8918	T_3 1.2358	T_4 1.5747
Coleoptera	T_2 1.3468	T_4 1.3842	T_1 2.5537	T_3 2.6078
Pauropoda	T_4 0.9015	T_1 2.4065	T_3 2.5446	T_2 4.1176

*) T_1 = old grassland (control), T_2 = cultivated and reseeded, T_3 = paraquat and reseeded, T_4 = dalapon and reseeded. Means underscored by the same line do not differ significantly. Continuous lines indicate 95 % level and broken lines indicate 99 % level of significance.

In general, populations of most groups of soil arthropods were significantly affected by the methods of reseeding at some stage during the 19-months period of study. The most common effect was initial reduction followed by recovery at varying rates, in some cases to levels significantly higher than control population levels. The Acari appear to have been more drastically affected than were the Collembola, particularly by cultivation and reseeding and by dalapon and reseeding, and significantly reduced populations in plots which had received the former treatment were still evident after 11 months. After 19 months Acarine populations appeared to have recovered in all treated plots. Collembolan populations were reduced initially by all methods of reseeding, but no significant ill effects were detected after 3 months, and after 19 months populations in

Table 8 Important species/genera ranked in order of abundance in the four treatments of Experiment I. Populations expressed as numbers of individuals encountered and as percentages of the total populations of Acari and Collembola

Old grassland	No.	%	Cultivated and reseeded	No.	%	Paraquat and reseeded	No.	%	Dalapon and reseeded	No.	%
Onychiurus spp.	3701	11.3	*Onychiurus* spp.	2742	12.4	*Isotoma notabilis* SCHÄFF.	2934	11.4	*Onychiurus* spp.	2662	12.5
Tullbergia krausbaueri (BÖRN.)	3313	10.2	*Folsomia quadrioculata* (TULLB.)	2398	10.8	*Tullbergia krausbaueri* (BÖRN.)	2609	10.1	*Folsomia quadrioculata* (TULLB.)	2173	10.2
Isotoma notabilis SCHÄFF.	2830	8.7	*Tullbergia krausbaueri* (BÖRN.)	2011	9.1	*Folsomia quadrioculata* (TULLB.)	2504	9.7	*Isotoma notabilis* SCHÄFF.	1843	8.7
Folsomia quadrioculata (TULLB.)	2631	8.1	*Pygmephorus* spp.	1493	6.7	*Onychiurus* spp.	2487	9.7	*Tullbergia krausbaueri* (BÖRN.)	1614	7.6
Minunthozetes semirufus (C. L. K.)	1610	4.9	*Minunthozetes semirufus* (C. L. K.)	1332	6.0	*Minunthozetes semirufus* (C. L. K.)	1579	6.1	*Minunthozetes semirufus* (C. L. K.)	1567	7.4
Variatipes spp.	1451	4.4	*Isotoma notabilis* SCHÄFF.	1329	6.0	*Pygmephorus* spp.	1076	4.2	*Eupodes* sp.	887	4.2
Eupodes sp.	1369	4.2	*Variatipes* spp.	1317	5.9	*Eupodes* sp.	1008	3.9	*Pygmephorus* spp.	829	3.9
Pygmephorus spp.	1072	3.3	*Hypogastrura denticulata* (BAGNALL)	915	4.1	*Hypogastrura denticulata* (BAGNALL)	742	2.9	*Variatipes* spp.	706	3.3
Isotoma viridis BOURL.	756	2.3	*Neelus minimus* WILLEM	652	2.9	*Variatipes* spp.	693	2.7	*Folsomia candida* (WILLEM)	480	2.3
Hypogastrura denticulata (BAGNALL)	552	1.7	*Eupodes* sp.	635	2.9	*Brachychthonius berlesei* (WILLM.)	596	2.3	*Isotoma viridis* BOURL.	472	2.2
Digamasellus scotarius SHEALS	548	1.7	*Isotoma viridis* BOURL.	352	1.6	*Isotoma viridis* BOURL.	427	1.7	*Brachychthonius berlesei* WILLM.	446	2.1
Brachychthonius berlesei (WILLM.)	437	1.3	*Liebstadia similis* (MICH.)	278	1.3	*Folsomia candida* (WILLEM)	380	1.5	*Hypogastrura denticulata* (BAGNALL)	438	2.1
Neelus minimus WILLEM	410	1.3	*Schwiebia* spp.	266	1.2	*Neelus minimus* WILLEM	312	1.2	*Liebstadia similis* (MICH.)	281	1.3
Rhodacarellus silesiacus WILLM.	387	1.2	*Pergamasus suecicus* TRÄG.	256	1.2	*Liebstadia similis* (MICH.)	307	1.2	*Schwiebia* spp.	220	1.0
Liebstadia similis (MICH.)	357	1.1				Tarsonemidae spp.	306	1.2	*Oppia minutus* EVANS	217	1.0
Total	32617		Total	22192		Total	25760		Total	21238	

the paraquat and reseeded plots were significantly higher than those in all other plots. The response of populations of the various Acarine and Collembolan groups and species considered to the reseeding methods varied a good deal with time and with method of reseeding. In general most groups seem to have been more adversely affected by cultivation and reseeding and by dalapon and reseeding than by paraquat and reseeding. In most cases there was an initial reduction in numbers following application of treatments. A notable exception was *M. semirufus*, populations of which were almost twice as high in cultivated and reseeded plots as in control plots after one month. Populations recovered at varying rates in the various treatments, often fluctuating violently from one sampling date to the next. After 19 months the only significant deleterious effect detected was a significant reduction in populations of *Isotoma notabilis* in cultivated and reseeded plots. After this period populations of Prostigmata, *Eupodes* sp. and *Pygmephorus* spp. in the ploughed and reseeded plots, *Eupodes* sp. and *I. notabilis* in the paraquat and reseeded plots, and *Eupodes* sp. in the dalapon and reseeded plots were significantly higher than those in the control plots.

3.2. Qualitative effects of treatments

The most abundant species in the four treatments are ranked in decreasing order of abundance in Table 8. By and large there was good agreement between the four treatments in regard to the identity of their important species and their relative abundance and there was no substantial replacement of one group of species by another in the reseeded plots.

The total numbers of major taxa encountered from the different treatment on each sampling date are given in Table 9 and in Table 10 the total numbers of species or species groups recorded from the 4 treatments are given. It is clear from these results that reseeding treatments did not have any appreciable effect on the diversity of the fauna.

Table 9 The numbers of higher taxa represented in the four treatments of Experiment I

Sampling date	Old grassland	Cultivated and reseeded	Paraquat and reseeding	Dalapon and reseeding
5. 5. '65	13	14	13	13
7. 7. '65	13	13	13	13
15. 11. '65	15	13	15	14
7. 3. '66	14	13	14	14
9. 11. '66	14	14	16	14
Overall (May '65—Nov. '66)	18	15	17	17

3.3. Effects of cultivation on vertical distribution

Two cores taken from each of the three cultivated plots to a depth of 15 cm on two occasions (5/1/'66 and 12/5/'66) provide information on the vertical distribution of the fauna to this depth in cultivated soil and allow comparisons to be made with the results of similar samplings of uncultivated plots which will be considered in detail in a future publication. Analysis of variance was carried out on fractional power transformed data for Acari and Collembola in the 0—7.5 cm and 7.5—15 cm strata and means were compared by means of DUNCAN's New Multiple Range Test (DUNCAN 1955). Results of this analysis are presented in Tables 11 and 12. These results indicate that, in the case of Collembola at least, cultivation significantly affected vertical distribution and that these animals were more evenly distributed to a depth of 15 cm in cultivated soil than in uncultivated.

Table 10 The numbers of species/genera represented in the four treatments of Experiment I

Sampling date		Old grassland	Cultivated and reseeded	Paraquat and reseeded	Dalapon and reseeded
5. 5. '65	Prostigmata	14	10	9	11
	Mesostigmata	22	23	21	22
	Cryptostigmata	19	20	18	16
	Astigmata	3	3	3	3
	Collembola	23	19	20	20
	Total Acari and Collembola	81	75	71	72
7. 7. '65	Prostigmata	15	16	14	13
	Mesostigmata	21	23	20	20
	Cryptostigmata	21	19	19	17
	Astigmata	4	4	2	4
	Collembola	21	16	21	22
	Total Acari and Collembola	82	78	76	76
15. 11. '65	Prostigmata	17	14	15	16
	Mesostigmata	26	23	29	25
	Cryptostigmata	17	19	20	17
	Astigmata	4	4	3	4
	Collembola	25	23	21	22
	Total Acari and Collembola	89	83	88	84
7. 3. '66	Prostigmata	14	12	18	16
	Mesostigmata	34	21	29	26
	Cryptostigmata	22	18	25	18
	Astigmata	3	4	3	3
	Collembola	29	23	26	26
	TotalAcari and Collembola	102	78	101	89
9. 11. '66	Prostigmata	14	15	14	14
	Mesostigmata	30	25	33	28
	Cryptostigmata	21	16	18	16
	Astigmata	3	5	5	3
	Collembola	27	26	30	28
	Total Acari and Collembola	95	87	100	89
Overall (May '65— Nov. '66)	Prostigmata	20	19	23	20
	Mesostigmata	39	34	40	34
	Cryptostigmata	25	25	25	25
	Astigmata	5	6	6	4
	Collembola	33	28	31	32
	Total Acari and Collembola	122	112	125	115

Table 11 Results of analysis of data on vertical distribution. Variance ratios

Group	Depth	1 F (treatments)	2 F (treatments × depths)	2 F (treatments × sampling dates)
Acari	0—15 cm	.014	.028	.34
Collembola	0—15 cm	46.53**	11.69**	.031
Collembola	0—7.5 cm	.006	—	—
Collembola	7.5—15 cm	3.95	—	—

(1) F with degrees of freedom $f_1 = 1, f_2 = 2$ *P 0.05 = 18.51 **P 0.01 = 98.49

(2) F with degress of freedom $f_1 = 1, f_2 = 13$ *P 0.05 = 4.67 **P 0.01 = 9.07

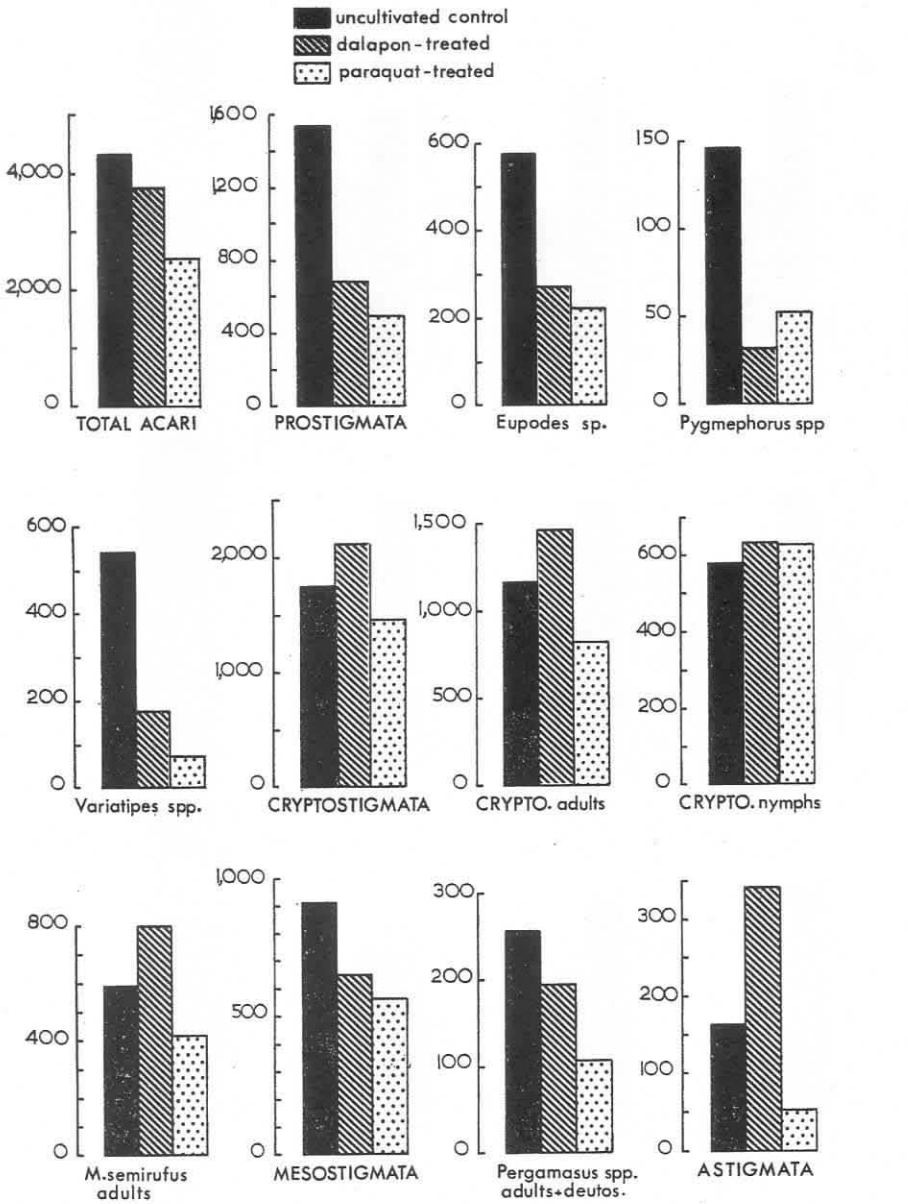


Fig. 7. Overall effects of treatments, August 1965—May 1966. Total numbers from 24 samples.

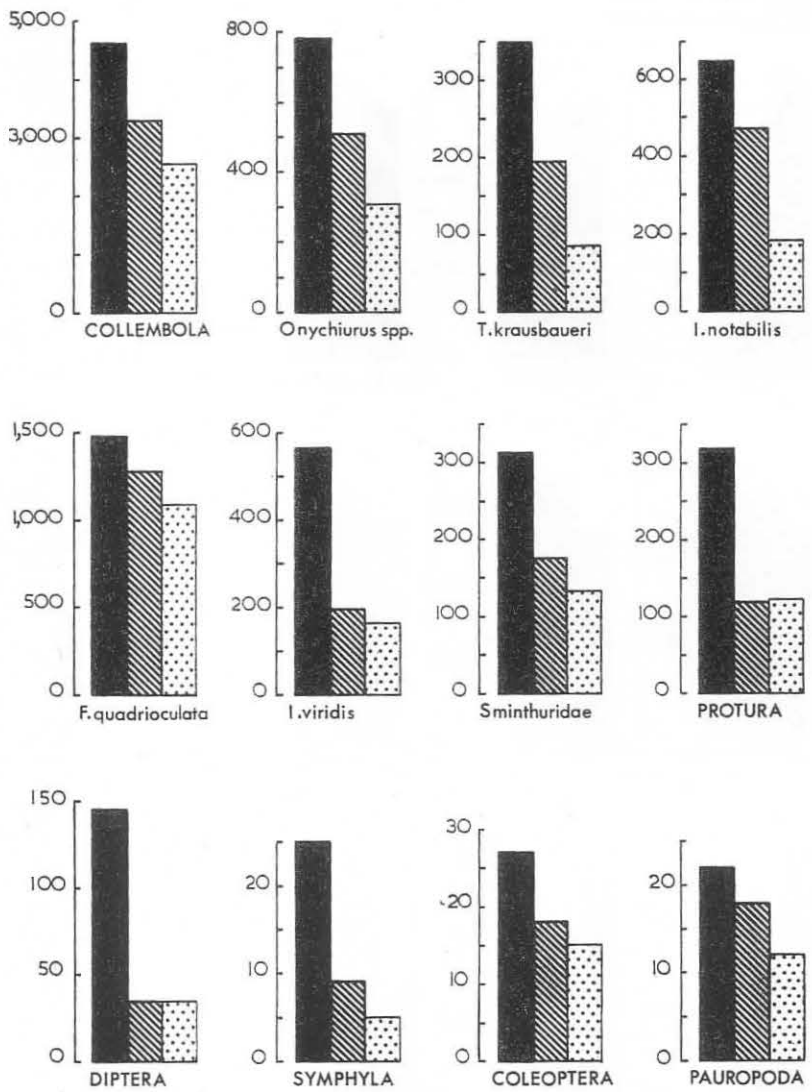


Fig. 8. Overall effects of treatments (continued).

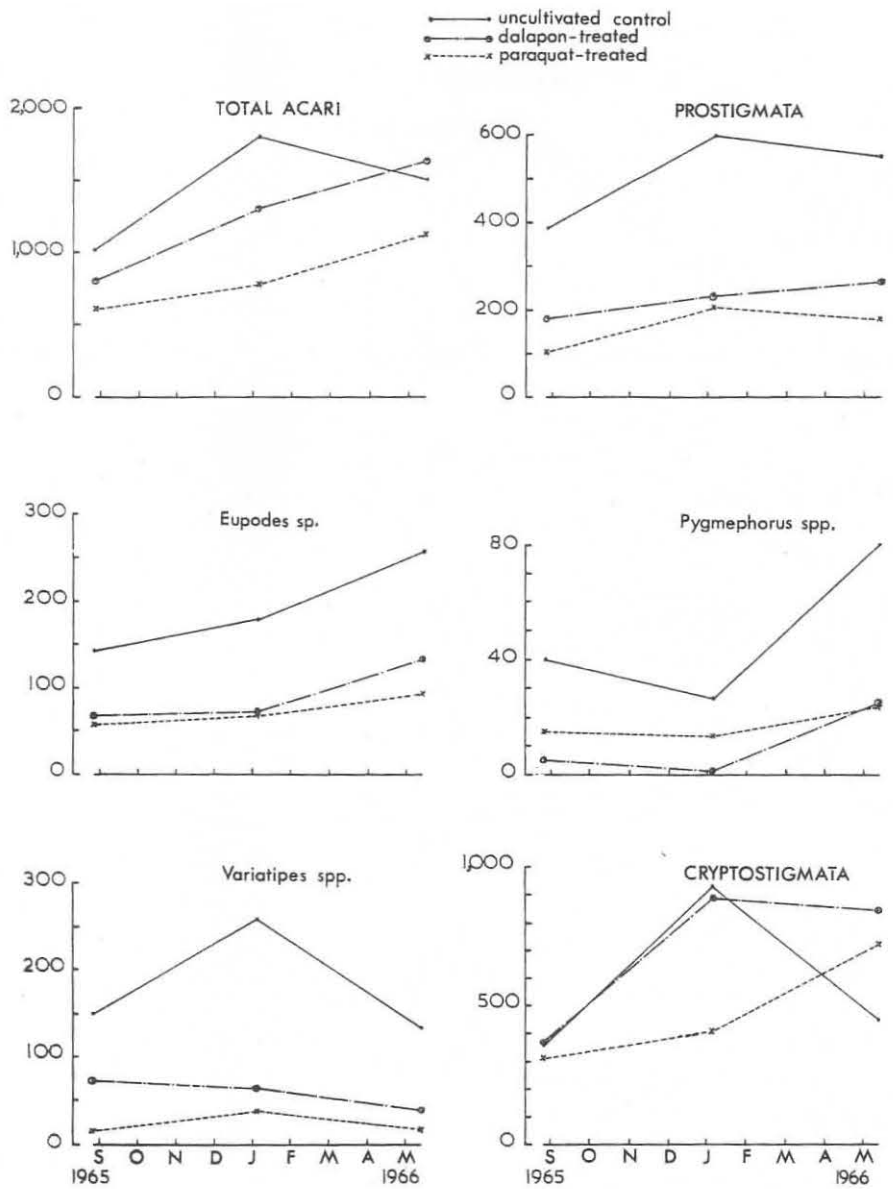


Fig. 9. Interaction of treatments with time, August 1965—May 1966. Total numbers from 8 samples.

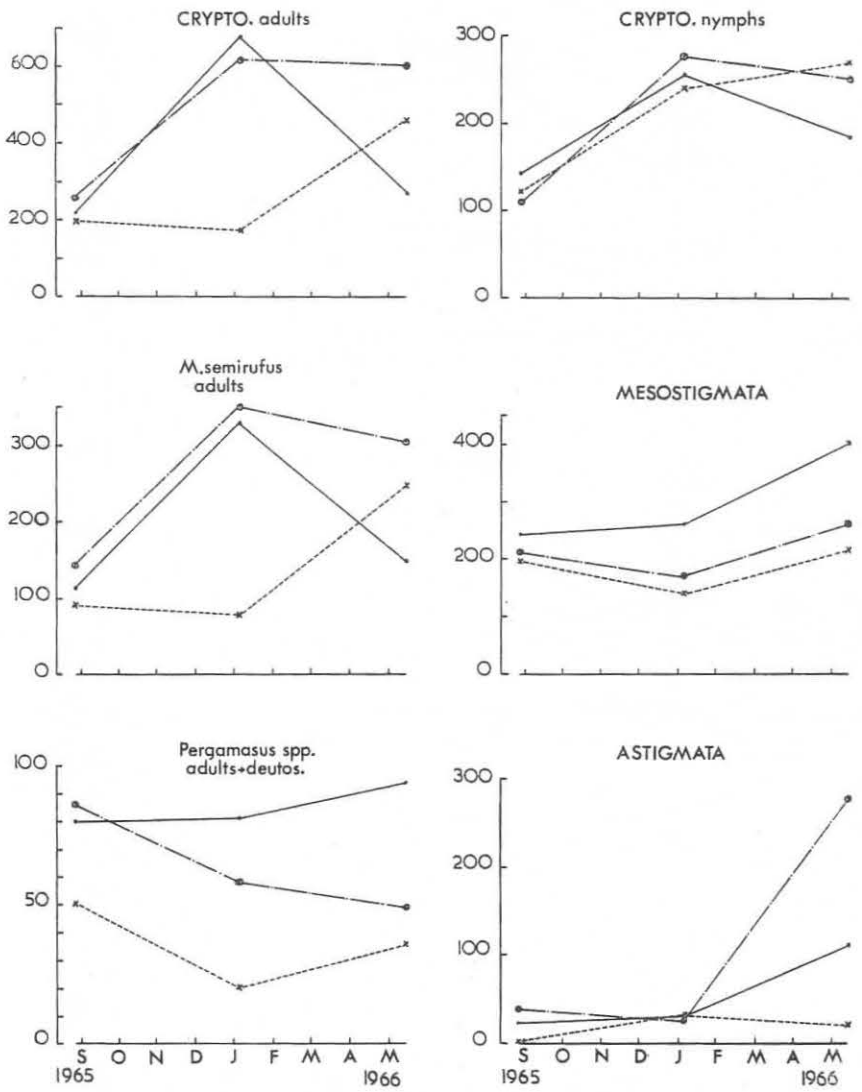


Fig. 10. Interaction of treatments with time (continued).

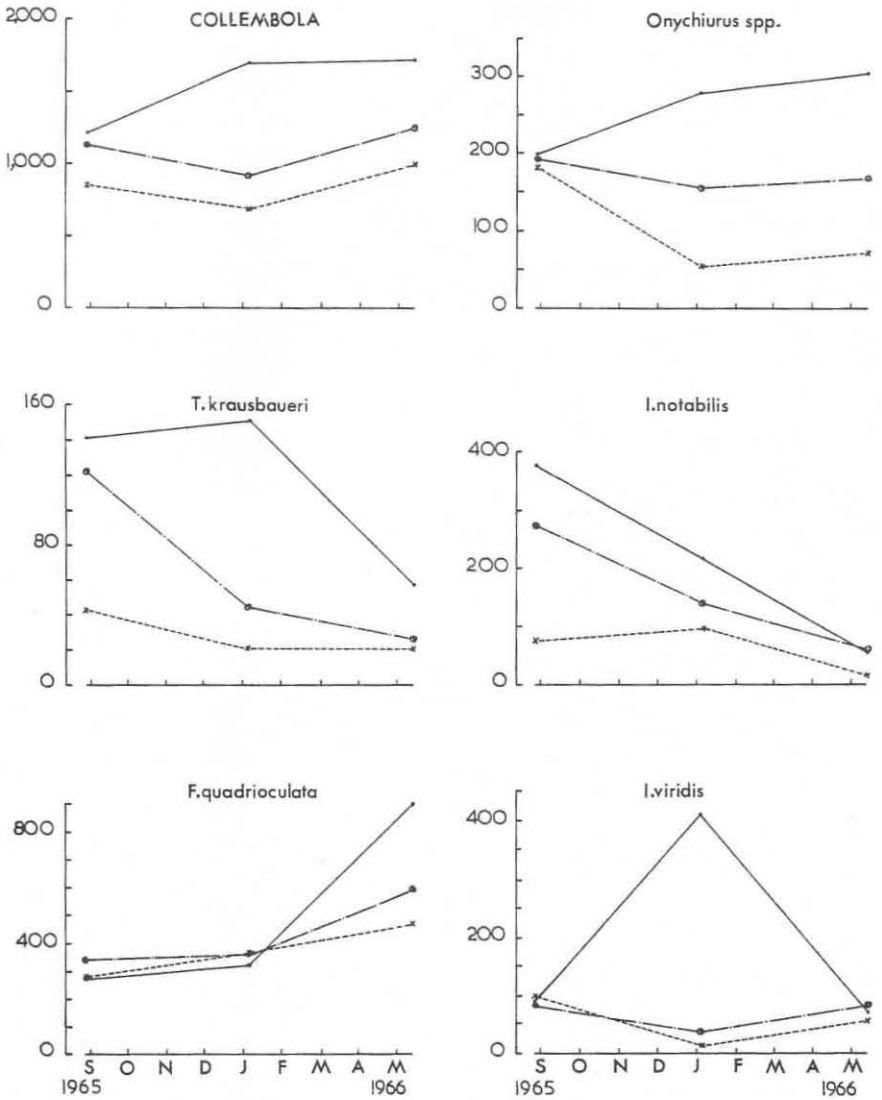


Fig. 11. Interaction of treatments with time (continued).

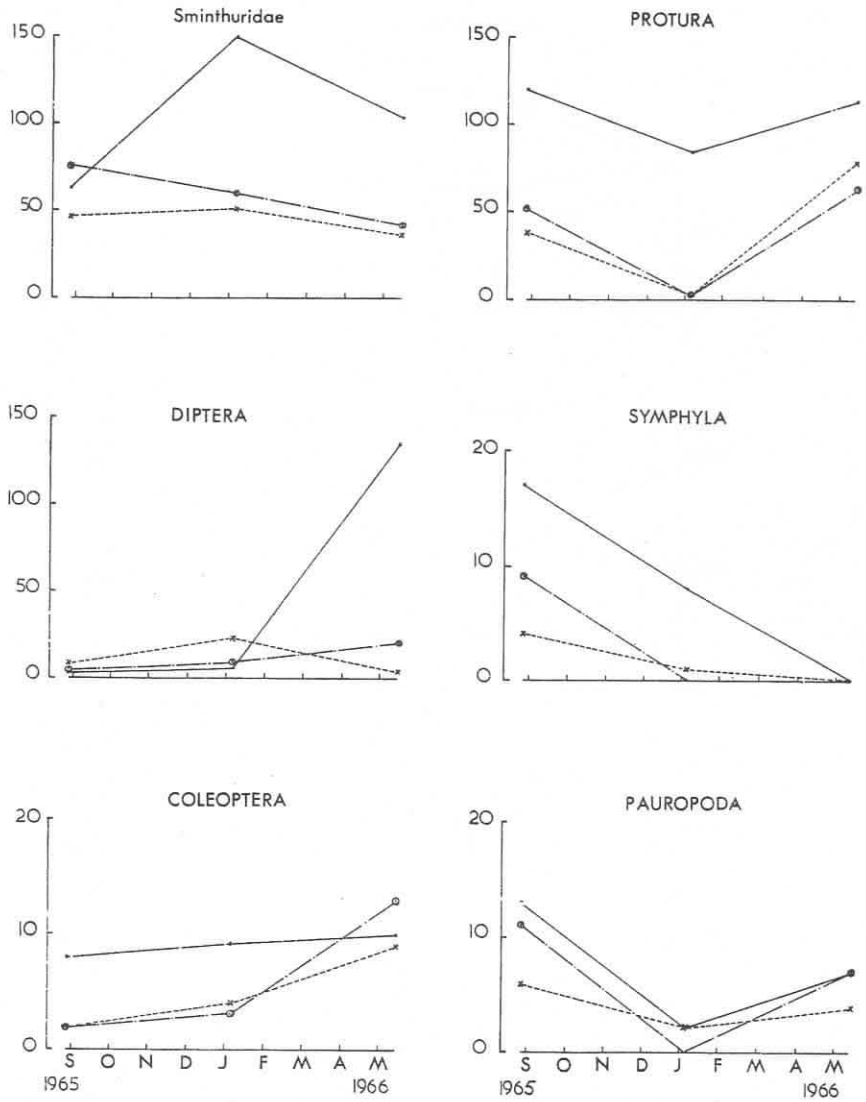


Fig. 12. Interaction of treatments with time (continued).

Table 12 Comparison of mean transformed numbers in different vertical soil strata by means of Duncan's New Multiple Range Test

Group	Depth	Treatment means*)	
Acari	0—15 cm	T_1 5.4392	T_2 5.4984
Collembola	0—15 cm	T_1 3.1515	T_2 3.4684
Collembola	0—7.5 cm	T_2 3.7608	T_1 3.7751
Collembola	7.5—15 cm	T_1 2.5279	T_2 3.1760

*) T_1 = uncultivated (old grassland) soil, T_2 = cultivated and reseeded soil. Means underscored by the same line do not differ significantly. Continuous lines indicate 95 % level and broken lines indicate 99 % level of significance.

4. Results of experiment II

4.1. Quantitative effects of treatments

Overall effects of treatments on populations of the main arthropod groups and species are shown in Figs. 7 and 8 and the effects of treatments with time are summarised in

Table 13 Results of analysis of data of Experiment II. Variance Ratios

	(Aug. '65—May '66) Overall		(26. 8. '65) First sampling	(5. 1. '66) Second sampling	(12. 5. '66) Third sampling
	F (treatments)	F (t×s)	F (treatments)	F (treatments)	F (treatments)
Total Acari	22.29*	2.22	8.25	14.58	3.20
Prostigmata	15.86	0.29	4.2	6.61	6.29
Eupodes sp.	16.51	0.57	7.26	13.11	3.23
Pygmephorus spp.	0.69	0.41	0.82	0.98	0.38
Variatipes spp.	4.29	0.36	1.80	10.0	1.85
Cryptostigmata (total)	1.37	5.27*	3.59	2.44	0.50
Cryptostigmata (adults)	2.21	6.22*	2.25	2.84	5.83
Cryptostigmata (nymphs)	0.10	0.15	0.12	0.16	0.11
Minunthozetes semirufus (C. L. K.)	2.04	3.09	1.31	1.91	15.18
Mesostigmata	1.32	0.94	0.13	1.5	0.97
Pergamasus spp.	5.63	1.55	0.53	4.42	1.9
Astigmata	0.97	2.36	2.26	0.15	1.89
Total Collembola	15.6	.92	1.81	8.0	0.75
Onychiurus spp.	5.45	.43	0.57	1.13	1.95
Tullbergia krausbaueri (BÖRN.)	10.17	1.97	13.17	8.12	1.09
Isotoma notabilis SCHÄFF.	2.45	.96	5.12	1.36	1.06
Folsomia quadrioculata (TULLB.)	94.23*	.20	0.55	3.2	7.25
Isotoma viridis BOURL.	2.74	2.67	0.006	36.4*	0.86
Sminthuridae	3.44	.34	0.11	1.78	28.63*
Protura	.66	.82	0.65	.84	0.09
Diptera	.10	4.0	2.33	5.55	1.6
Coleoptera	.67	.60	12.6	9.0	0.07
Pauropoda	7.7	.26	1.78	—	0.14

F (treatments) with degrees of freedom $f_1 = 2$, $f_2 = 2$, *P 0.05 = 19.0, **P 0.01 = 99.00
F (t×s) with degrees of freedom $f_1 = 4$, $f_2 = 6$, *P 0.05 = 4.53, **P 0.01 = 9.15
(t × s = treatments × sampling dates)

Table 14 Results of comparisons of treatment means by means of Duncan's New Multiple Range test. Analysis of fractional power transformed data

Group or species	First sampling (26. 8. '65) Treatment means*)			Second sampling (5. 1. '66) Treatment means*)			Third sampling (12. 5. '66) Treatment means*)			Overall (Aug. '65—May '66) Treatment means*)		
Total Acari	T_3 3.7830	T_2 3.9197	T_1 4.0417	T_3 3.8696	T_2 4.2345	T_1 4.4701	T_3 4.1048	T_1 4.3779	T_2 4.3906	T_3 3.9191	T_2 4.1816	T_1 4.2966
Prostigmata	T_3 1.4917	T_2 1.6222	T_1 1.8495	T_3 1.6720	T_2 1.6846	T_1 2.0179	T_3 1.6190	T_2 1.7425	T_1 1.9735	T_3 1.5942	T_2 1.6831	T_1 1.9470
Eupodes sp.	T_3 1.1669	T_2 1.1788	T_1 1.2572	T_3 1.1404	T_2 1.1557	T_1 1.2943	T_3 1.1764	T_2 1.2165	T_1 1.3177	T_3 1.1612	T_2 1.1836	T_1 1.2897
Pygmephorus spp.	T_2 0.5968	T_3 0.8866	T_1 2.4479	T_2 0.0000	T_3 1.6962	T_1 2.2630	T_3 2.4209	T_2 2.6517	T_1 4.0027	T_2 1.0828	T_3 1.6679	T_1 2.9054
Variatipes spp.	T_3 1.0115	T_2 1.0238	T_1 1.0484	T_3 1.0243	T_2 1.0313	T_1 1.0687	T_3 1.0115	T_2 1.0224	T_1 1.0443	T_3 1.0158	T_2 1.0259	T_1 1.0538
Cryptostigmata (total)	T_3 .0124	T_1 .0129	T_2 .0130	T_3 .0130	T_2 .0160	T_1 .0160	T_1 .0139	T_2 .0150	T_3 .0161	T_3 .0135	T_1 .0143	T_2 .0150
Cryptostigmata (adults)	T_3 3.5595	T_1 3.6948	T_2 3.9411	T_3 2.9424	T_2 5.3889	T_1 5.6003	T_1 4.0680	T_3 4.8764	T_2 5.6208	T_3 3.7928	T_1 4.4544	T_2 4.9836
Cryptostigmata (nymphs)	T_3 1.3427	T_2 1.3491	T_1 1.3668	T_3 1.4827	T_1 1.4988	T_2 1.5074	T_1 1.4432	T_3 1.4609	T_1 1.4879	T_3 1.4288	T_1 1.4363	T_2 1.4481
Minunthozetes semirufus (C. L. K.)	T_3 1.1724	T_1 1.2010	T_2 1.2111	T_3 1.1257	T_2 1.2763	T_1 1.2851	T_1 1.2135	T_3 1.2578	T_2 1.2935	T_3 1.1853	T_1 1.2332	T_2 1.2603
Mesostigmata	T_3 6.1005	T_2 6.1612	T_1 6.1850	T_3 4.8860	T_2 5.8235	T_1 6.2991	T_3 6.1286	T_2 6.2822	T_1 6.8070	T_3 5.7050	T_2 6.0890	T_1 6.4304
Pergamasus spp.	T_3 1.0159	T_1 1.0181	T_2 1.0190	T_3 1.0060	T_2 1.0156	T_1 1.0202	T_3 1.0114	T_2 1.0152	T_1 1.0214	T_3 1.0111	T_2 1.0166	T_1 1.0199
Astigmata	T_3 0.2954	T_1 1.8864	T_2 2.9112	T_1 2.5500	T_2 2.5724	T_3 2.9864	T_2 1.9778	T_3 2.0255	T_1 4.4284	T_3 1.7691	T_2 2.4871	T_1 2.9550
Total Collembola	T_3 1.3623	T_2 1.3888	T_1 1.3945	T_3 1.3171	T_2 1.3712	T_1 1.4179	T_3 1.3789	T_2 1.3923	T_1 1.4202	T_3 1.3527	T_2 1.3841	T_1 1.4109
	T_3	T_2	T_1	T_3 0.4442	T_2 0.7195	T_1 0.8687	T_3 0.5615	T_2 0.7228	T_1 0.8137	T_3 0.5953	T_2 0.7440	T_1 0.8525

Onychiurus spp.	T_3 0.7801	T_2 0.7897	T_1 0.8751	T_3 0.4443	T_2 0.7195	T_1 0.8687	T_3 0.5615	T_2 0.7228	T_1 0.8137	T_3 0.5953	T_2 0.7440	T_1 0.8525
Tullbergia krausbaueri (Börn.)	T_3 1.1562	T_2 1.2825	T_1 1.2962	T_3 1.0712	T_2 1.1468	T_1 1.3109	T_3 1.0721	T_2 1.0991	T_1 1.1730	T_3 1.0998	T_2 1.1761	T_1 1.2600
Isotoma notabilis Schäff.	T_3 1.0979	T_2 1.2068	T_1 1.2266	T_3 1.0996	T_2 1.1510	T_1 1.1979	T_3 1.0314	T_2 1.0719	T_1 1.1055	T_3 1.0763	T_2 1.1432	T_1 1.1767
Folsomia quadrioculata (Tullb.)	T_3 4.2190	T_1 4.3509	T_2 4.4869	T_3 3.8987	T_1 4.3207	T_2 4.4158	T_3 4.7471	T_2 4.9777	T_1 5.1381	T_3 4.2883	T_1 4.6032	T_2 4.6268
Isotoma viridis Bourl.	T_1 3.1721	T_3 3.1889	T_2 3.3082	T_3 0.9270	T_2 2.2876	T_1 4.4721	T_3 2.8917	T_1 2.9703	T_2 3.7930	T_3 2.3359	T_2 3.1296	T_1 3.5381
Sminthuridae	T_3 0.7458	T_2 0.8173	T_1 0.9077	T_2 0.6663	T_3 0.6973	T_1 1.1135	T_3 .5745	T_2 .6422	T_1 1.0532	T_3 0.6725	T_2 0.7086	T_1 1.0248
Protura	T_3 2.1713	T_2 2.5686	T_1 3.1826	T_2 0.1746	T_3 0.1746	T_1 2.3192	T_2 3.3818	T_1 3.6516	T_3 3.7115	T_3 2.0191	T_2 2.0417	T_1 3.0511
Diptera	T_1 0.0000	T_2 0.3967	T_3 1.1900	T_1 0.3967	T_2 1.4608	T_3 2.8445	T_3 0.0000	T_2 1.3752	T_1 3.1794	T_2 1.0775	T_1 1.1920	T_3 1.3448
Coleoptera	T_2 0.0000	T_3 .3403	T_1 1.1751	T_2 0.0000	T_3 0.0000	T_1 1.0208	T_1 1.1751	T_3 1.3294	T_2 1.8273	T_3 0.5565	T_2 0.6091	T_1 1.1236
Pauropoda	T_3 0.8441	T_2 1.9570	T_1 2.5296	T_1 0.0000	T_2 0.0000	T_3 0.0000	T_3 .6352	T_2 .6352	T_1 1.2704	T_3 0.4931	T_2 0.8641	T_1 1.2667

*) T_1 = old grassland (control), T_2 = dalapon, T_3 = paraquat. Means underscored by the same line do not differ significantly. Continuous lines indicate 95 % level and broken lines indicate 99 % level of significance.

Table 15 Important species/genera ranked in order of abundance in the three treatments of Experiment II. Populations expressed as numbers of individuals and as percentages of the total populations of Acari and Collembola

Old grassland	Nos.	%	Dalapon	Nos.	%	Paraquat	Nos.	%
Folsomia quadrioculata (TULLB.)	1485	16.6	*Folsomia quadrioculata* (TULLB.)	1282	18.2	*Folsomia quadrioculata* (TULLB.)	1095	21.6
Onychiurus spp.	781	8.7	*Minunthozetes semirufus* (C. L. K.)	794	11.3	*Hypogastrura denticulata* (BAGNALL)	453	9.0
Isotoma notabilis SCHÄFF.	649	7.3	*Onychiurus* spp.	511	7.3	*Minunthozetes semirufus* (C. L. K.)	413	8.2
Minunthozetes semirufus (C. L. K.)	586	6.5	*Isotoma notabilis* SCHÄFF.	471	6.7	*Onychiurus* spp.	306	6.0
Eupodes sp.	574	6.4	*Hypogastrura denticulata* (BAGNALL)	302	4.3	*Eupodes* sp.	218	4.4
Isotoma viridis BOURL.	564	6.3	*Eupodes* sp.	269	3.8	*Isotoma notabilis* SCHÄFF.	183	3.6
Variatipes spp.	541	6.0	*Liebstadia similis* (MICH.)	245	3.5	*Isotoma viridis* BOURL.	164	3.2
Tullbergia krausbaueri (BÖRN.)	350	3.9	*Isotoma viridis* BOURL.	196	2.8	*Liebstadia similis* (MICH.)	125	2.5
Hypogastrura denticulata (BAGNALL)	169	1.9	*Tullbergia krausbaueri* (BÖRN.)	193	2.7	Tarsonemidae spp.	84	1.7
Liebstadia similis (MICH.)	168	1.9	*Variatipes* spp.	174	2.5	*Tullbergia krausbaueri* (BÖRN.)	84	1.7
Pygmephorus spp.	146	1.6	*Oppia clavipectinata* (MICH.)	113	1.6	*Variatipes* spp.	70	1.4
Scutacarus crassisetus plumosus (PAOLI)	124	1.4	*Retetydeus/Lorryia*	93	1.3	*Oppia clavipectinata* (MICH.)	67	1.3
Oppia clavipectinata (MICH.)	110	1.2	*Achipteria coleoptrata* (L.)	79	1.1	*Sminthurinus auerus* (LUBB.)	62	1.2
Folsomia montigena STACH	107	1.2				*Digamasellus scotarius* SHEALS	55	1.1
Neelus minimus WILLEM	102	1.1				*Pygmephorus* spp.	52	1.0
Total	8951		Total	7040		Total	5059	

Figs. 9—12. Results of analysis of variance of fractional power transformed data and comparisons of treatment means are given in Tables 13 and 14. While there were considerable differences between the numbers of many groups and species recovered from the different treatments-populations generally being much lower in plots which had been treated with the herbicides than in the control plots — in very few cases were these differences statistically significant. However, the results do show that the use of the herbicide paraquat in particular adversely affected populations of soil Acari and Collembola, at least temporarily. Paraquat appeared to affect the fauna more drastically than did Dalapon — significantly so in the case of Acari, and indeed in the case of 1 species of the latter group (*M. semirufus*) populations were significantly higher in the dalapon-treated plots than in the control plots 10 months after application of the herbicides.

4.2. Qualitative effects of treatments

By and large there was no substantial replacement of one group of species by another in the chemically treated plots (Table 15). The herbicidal treatments do not appear to have appreciably affected the diversity of the faune in terms of the numbers of major taxonomic groups occurring (Table 16), but fewer species of Acari and Collembola occurred in the herbicide treated plots than in the control plots on the first and second sampling dates (Table 17).

Table 16 The numbers of species/genera represented in the three treatments of Experiment 2

Sampling		Old grassland	Dalapon	Paraquat
26. 8. '65	Prostigmata	10	9	8
	Mesostigmata	20	20	15
	Cryptostigmata	15	14	15
	Astigmata	2	3	1
	Collembola	22	15	20
	Total Acari and Collembola	69	61	59
5. 1. '66	Prostigmata	16	10	11
	Mesostigmata	26	19	16
	Cryptostigmata	22	16	15
	Astigmata	2	1	2
	Collembola	22	16	16
	Total Acari and Collembola	88	62	60
12. 5. '66	Prostigmata	13	12	11
	Mesostigmata	20	23	22
	Cryptostigmata	16	18	17
	Astigmata	3	2	4
	Collembola	27	24	19
	Total Acari and Collembola	79	79	73
Overall (Aug. '65— May '66)	Prostigmata	17	16	13
	Mesostigmata	32	27	25
	Cryptostigmata	23	20	21
	Astigmata	4	4	4
	Collembola	30	25	22
	Total Acari and Collembola	106	92	85

Table 17 The numbers of higher taxa represented in the three treatments of Experiment 2

Sampling date	Old grassland	Dalapon	Paraquat
26. 8. '65	12	13	10
5. 1. '66	13	10	10
12. 5. '66	13	13	13
Overall (Aug. '65—May '66)	15	15	14

5. Discussion

It is unlikely that the herbicides themselves exerted any great direct effect on the fauna since they are non-persistent chemicals of low insecticidal properties and since they were not worked into the soil. The observed effects on the fauna following their application were probably brought about indirectly by their drastic effects on the sward and hence on soil environmental factors such as moisture content, aeration, temperature and food supply.

The differential response of the fauna to the chemicals may have been due to differential herbicidal activity, for it is known that the 2 herbicides do not affect a particular sward in the same way. Paraquat, for instance, is not effective against white clover (ARNOTT et al., 1966); dalapon is a better killer of low fertility grasses than paraquat (BLACKMORE 1964); paraquat being very rapid in action shows its maximum effect on the sward within 10 days whereas dalapon takes 4 to 6 weeks to achieve its maximum effect (ALLEN 1965).

Adverse effects on the fauna of the top 7.5 cm of cultivated soil are no doubt attributable to adverse environmental conditions induced by the removal of plant cover coupled with disturbance of the soil during cultivation. Results of sampling to a depth of 15 cm showed that such adverse effects were compensated for by a richer fauna at a depth of 7.5—15 cm than was found at a corresponding depth in uncultivated soil, so that the overall effect of cultivation on the fauna did not appear to be deleterious and, in the case of Collembola at least, populations were actually increased. This enhanced faunal activity in the deeper layers of cultivated soil was probably a result of the plentiful supply of food in the form of decaying organic matter available to the fauna following the incorporation of the old sward into the soil. These results confirm the findings of THOMPSON (1924) and MURPHY (1952) that the fauna is more evenly distributed vertically in cultivated soil than in uncultivated. It is interesting that significant differences between the effects of the two methods of surface seeding used in Experiment I on many animal groups occurred and that the trends apparent in this experiment were the reverse of those in Experiment II. This suggests that factors such as time of application, interaction of chemicals with surface cultivation and differential growth of the newly sown sward may be important in determining the response of animal populations to surface seeding following chemical destruction of the sward.

Recovery of the fauna as the newly-sown swards became established was probably due to the restoration of favourable environmental conditions — moisture conditions in particular — in the topsoil on the restoration of plant cover. Similar recovery accompanying growth of vegetation was noted by THOMPSON (1924) and SHEALS (1956).

It is difficult to say what effect, if any, such effects on soil fauna as were noted at Lyons hill following the various treatments have on soil fertility, particularly since the importance of the fauna in soil biological processes is still not clear, nor is it clear how changes in their numbers may influence these processes. However, soil conditions which support a fauna rich in species and in individuals are also those conditions which are most

favourable for plant growth and factors which bring about a drastic impoverishment of the fauna must also be considered detrimental to soil fertility. In view of the fact that no serious reduction in the diversity of the fauna occurred and that depletion of populations was only temporary it can be concluded that any adverse effects of the treatments were only temporary.

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